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PATENT
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants	:	Xiaobing SUN et al.
Serial No.	:	09/989,938
Filed	:	November 21, 2001
For	:	RESOURCE ALLOCATION IN CDMA WIRELESS COMMUNICATION SYSTEMS
Art Unit	:	2631

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Glenn F. Savit, Reg. No. 37,437
Name of Applicant, Assignee or Registered Representative

Signature

March 14, 2002
Date of Signature

CLAIM OF PRIORITY

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

In support of the claim of priority under 35. U.S.C. § 119 asserted in the Declaration accompanying the above-entitled application, as filed, please find enclosed herewith a certified copy of Singapore Application No. 200006943-5, filed in Singapore on 24 November 2000 forming the basis for such claim.

Acknowledgment of the claim of priority and of the receipt of said certified copy(s) is requested.

Respectfully submitted,

FROMMER LAWRENCE & HAUG LLP
Attorneys for Applicants

By: _____
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Enclosure

REGISTRY OF PATENTS
SINGAPORE

This is to certify that the annexed is a true copy of the following Singapore patent application as filed in this Registry.

Date of Filing	:	24 NOVEMBER 2000
Application Number	:	200006943-5
Applicant(s)	:	SONY ELECTRONICS (SINGAPORE) PTE LTD
Title of Invention	:	RESOURCES ALLOCATION IN CDMA WIRELESS COMMUNICATION SYSTEMS

CERTIFIED COPY OF
PRIORITY DOCUMENT

Sharmaine Wu Shee Mei
*Assistant Registrar
for REGISTRAR OF PATENTS
SINGAPORE

2000069435
24 NOV 2000

PATENTS FORM 1

SINGAPORE
THE PATENTS ACT
(CHAPTER 221)
PATENTS RULES

Rule 19

The Registrar of Patents
Registry of Patents

REQUEST FOR THE GRANT OF A PATENT

THE GRANT OF A PATENT IS REQUESTED BY THE UNDERSIGNED ON THE BASIS OF THE PRESENT APPLICATION.

I. Title of Invention	RESOURCE ALLOCATION IN CDMA WIRELESS COMMUNICATION SYSTEMS	
II. Applicant (s) *(See note 2)*	(a) Name	Sony Electronics (Singapore) Pte Ltd
	Body Description / Residency	A company organized and existing under the laws of Singapore
	Street Name & Number	Singapore Research Laboratory 10 Science Park Road #03-08 The Alpha, Singapore Science Park II
	City	
	State	
	Country	Singapore 117684
	(b) Name	
	Body Description / Residency	
	Street Name & Number	
	City	
	State	
	Country	
	(c) Name	
	Body Description / Residency	
	Street Name & Number	
	City	
	State	
	Country	

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24 NOV 2000

III. Declaration of Priority (see note 3)				
	Country / Country Designated		File No.	
	Filing Date			
	Country / Country Designated		File No.	
	Filing Date			
	Country / Country Designated		File No.	
	Filing Date			
	Country / Country Designated		File No.	
	Filing Date			

IV. Inventors (*See note 4*) (a) The applicant(s) is/are the sole/joint inventor(s).	☐ YES ☒ NO
(b) A statement on Patents Form 8 is/will be furnished.	☒ YES ☐ NO
V. Name of Agent (if any) (*See note 5*)	**LLOYD WISE**

VI. Address for Service (*See note 6*)				
	Block/Hse No		Level No	
	Unit No/PO Box	P O BOX 636	Postal Code	910816
	Street Name			
	Building Name	TANJONG PAGAR POST OFFICE		

VII. Claiming an earlier filing date under section 20 (3), 26(6) or 47(4) (*see note 7*)		
	Application No	
	Filing Date	

[Please tick in the relevant space provided]:

( ) Proceeding under rule 27(1)(a).
Date on which the earlier application was amended = _____

or

( ) Proceeding under rule 27(1)(b).

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24 NOV 2000

VIII. Invention has been displayed at an International Exhibition *(See note 8)*	☐ YES ☒ NO		
IX. Section 114 requirements *(See note 9)*	The invention relates to and/or used a micro-organism deposited for the purposes of disclosure in accordance with Section 114 with a depository authority under the Budapest Treaty ☐ YES ☒ NO		
X. Check List *(To be filled in by applicant or agent)*	A. The application contains the following number of sheet(s) :-		
	1. Request.	4	Sheets
	2. Description.	7	Sheets
	3. Claim (s).	3	Sheets
	4. Drawing (s).	1	Sheets
	5. Abstract.	1	Sheets
	B. The application as filed is accompanied by :-		
	1. Priority document.		
	2. Translation of priority document.		
	3. Statement of Inventorship & right to grant	3	
	4. International Exhibition Certificate.		
XI. Signature (s) *(See note 10)*	Applicant (a)		
	Date	24 November 2000	
	Applicant (b)		
	Date		
	Applicant (c)		
	Date		

NOTES :

1. This form when completed, should be brought or sent to the Registry of Patents together with the prescribed fee and 3 copies of the description of the invention, and of any drawings.

2. Enter the name and address of each applicant in the spaces provided at paragraph II. Names of individuals should be indicated in full and the surname or family name should also underlined. The names of all partners in a firm must be given in full. The place of residence of each individual should also be furnished in the space provided. Bodies corporate should be designated by their corporate name and country of incorporation and, where appropriate, the state of incorporation within that country should be entered where provided. Where more than three applicants are to be named, the names and address of the fourth and any further applicants should be given on a separate sheet attached to this Form together with the signature of each of these further applicants.

3. The declaration of priority at paragraph III should state the date of the previous filing, and the country in which it was made and indicate the file number, if available. When the application relied upon in an International Application or a regional patent application e.g. European patent application, one of the countries designated in that application [being one falling under the Patents (Convention Countries) Order] should be identified and the name of that country should be entered in the space provided.

4. Where the applicant or applicants is/are the sole inventor or the joint inventors, paragraph IV should be completed by marking the "YES' Box in the declaration (a) and the 'NO' Box in the alternative statement (b). Where this is not the case, the 'NO' Box in declaration (a) should be marked and a statement will be required to be filed on Patents Form 8.

5. If the applicant has appointed an agent to act on his behalf, the agent's name should be indicated in the spaces available at paragraphs V.

6. An address for service in Singapore to which all documents may be sent must be stated at paragraph VI. It is recommended that a telephone number be provided if an agent is not appointed.

7. When an application is made by virtue of section 20(3), 26(6) or 47(4), the appropriate section should be identified at paragraph VII and the number of the earlier application or any patent granted thereon identified. Applicants proceeding under section 26(6) should identify which provision in rule 27 they are proceeding under. If the applicants are proceeding under rule 27(1)(a), they should also indicate the date on which the earlier application was amended.

8. Where the applicant wishes an earlier disclosure of the invention by him at an International Exhibition to be disregarded in accordance with section 14(4)(c), then the 'YES' box at paragraph VIII should be marked. Otherwise the 'NO' box should be marked.

9. Where in disclosing the invention the application refers to one or more micro-organisms deposited with a depository authority under the Budapest Treaty, then the 'YES' box at paragraph XI should be marked. Otherwise the 'NO' box should be marked.

10. Attention is drawn to rules 90 and 105 of the Patent Rules. Where there are more than three applicants, see also Note 2 above.

11. Applicants resident in Singapore are reminded that if the Registry of Patents considers that an application contains information the publication of which might be prejudicial to the defence of Singapore or the safety of the public, it may prohibit or restrict its publication or communication. Any person resident in Singapore and wishing to apply for patent protection in other countries must first obtain permission from the Singapore Registry of Patents unless they have already applied for a patent for the same invention in Singapore. In the latter case, no application should be made overseas until at least two months after the application has been filed in Singapore.

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Our Ref: SP4160

Resource Allocation in CDMA wireless communication systems

The present invention relates to resource allocation in code-division-multiple-access (CDMA) wireless communication systems, and in particular to the problem of assigning spreading codes to users under different multipath channel conditions.

CDMA is widely used in modern wireless communication systems. For example, one known variety of CDMA system [1] includes multiple base stations each defining a "cell", that is an area surrounding the base station in which transmissions from the base station may be received. Users are provided with mobile communications devices (e.g. mobile phones) which communicate with the base station of the cell in which they are located using CDMA signals transmitted in each direction ("downlink" to the mobile device, and "uplink" to the base station). The CDMA signals for a given user are generated using a spreading code for each user. Each spreading code varies at time increments called "chips" and has a period of N chips (a "symbol"). A signal bit is sent between each mobile device and the base station during each symbol.

In current systems, the spreading codes are assigned by a central resource management unit for each user. This may not be the optimal resource allocation strategy, especially when there is multipath propagation, illustrated in Fig. 1, in which a CDMA signal from a CDMA transmitter 1 (which may be one of a base station or a mobile receiver) is transmitted to a CDMA receiver 3 (which may be the other one of a base station or a mobile receiver) via different paths 5. The components of the multipath signal are added together at the receiving antenna 7. This addition can be constructive or destructive, i.e. the receiving signal amplitude can be larger or less than that of a single path signal.

If the signal bandwidth is larger than channel coherence bandwidth, the multipath delays will spread over many chip intervals. In this case, a specific receiver structure called a RAKE receiver may be appropriate [2]. The RAKE receiver makes use of the multipath signal energies at the symbol-level, i.e. it coherently adds the different delayed multipath signals after despreading each of them. Thus some signal gain is obtained.

A method has been proposed recently which dynamically assigns the spreading codes and delays of multiple users with the object of minimising the mutual cross-correlation among them in the receiver [3]. This method helps to avoid multiple access interference (MAI) which arises when a given user receives signals from multiple transmitters. However, the method can only be used in the uplink of a cellular CDMA system by a base station which knows all the spreading codes for all users. Also, the algorithm to determine the spreading codes is complex and can only be implemented recursively. Another drawback of the method is if the number of users in a cell is low, the benefit of the method decreases.

The present invention aims to provide a new and useful method for assigning spreading codes in a CDMA communication system. This general problem has relevance for many different fields including wireless cellular communications, satellite communications, local area networks, personal area networks and wireless local loops. One of its major applications is to assign spreading codes of a CDMA system.

In general terms, the present invention proposes matching the spreading code and the multipath channel of each receiver, so that the signal energies of different paths add constructively instead of destructively at the antenna of the receiver. This may make it possible to make full use of the multipath signal energies. The benefit of the proposed method is most evident for a frequency-

selective channel in which the multipath delay profile spreads over many chip intervals.

Important advantages of a preferred embodiment of the invention compared to the known systems described above are that: (1) it makes fuller use of the multipath signal energies than does the RAKE receiver [2]; (2) by selecting appropriate spreading codes, the multipath channel itself delays and modifies the signals and makes most of the mulitpath components contribute constructively to the sum of the received signal; (3) as input data the embodiment employs only channel estimation information, and the auto-correlation functions of the spreading codes; (4) the algorithm to find the best spreading codes may be very simple; and (5) it can be used in both ends of a radio link (for cellular communications, both uplink and downlink).

Preferred features of the invention will now be described, for the sake of illustration only, with reference to the following figures in which:

Figure 1 shows a multipath channel between a transmitter and a receiver; and

Figure 2 is a block diagram of a receiver which is an embodiment of the present invention.

A procedure according to the invention for dynamic assignment of spreading codes, which may be performed by the CDMA receiver 3 of Fig. 1, will be explained with reference to Figure 2.

(1) Signals received by the aerial 7 are CDMA signals which use spreading codes to spread the symbols of the transmitted data. These signals are propagated over a multipath channel where the multipath delays are longer than at least one chip's period. The received signal is input to circuitry shown in Fig. 2, in which it is sent to a channel estimation or channel prediction unit

9, a RAKE receiver unit 11 as described in [2], and a unit 13 which informs the RAKE receiver unit 11 of changes in the receiver's spreading code.

(2) In the unit 9, the parameters of the multipath propagating channel to the receiver are estimated in real-time by a method which may either be training-based (i.e. if the aerial 7 receives signals encoding known data) or blind. Two such known methods are the training-based maximum-likelihood algorithm or blind-based moment algorithm. Alternatively, unit 9 may predict the channel parameters based on other information.

The channel parameters are here denoted by a set of L complex channel coefficients c(j), where L is the maximum delay expressed as a number of chip periods. Specifically, the multipath channel may be modelled as a tap-delay-line structure with complex coefficients: c(0), c(1),..., c(L-1).

(3). The unit 9 sends the estimated channel parameters to a spreading code selection unit 15 where the spreading codes with better performance are selected based on the channel parameters and the auto-correlation functions of all the available spreading codes.

Suppose that the invention is used to select a spreading code from K possibilities, labelled by $k = 1,\ldots,K$. For a specific kind of spreading code (for example Gold codes or Walsh codes) of a specific code length, it is easy to calculate the auto-correlation function r_s (k, i) of the k^{th} code at the i^{th} delay.

The best code over the multipath channel may be determined as the k given by:

$$k = \arg \max_k \left\{ m(k) = \mathrm{Re}[\sum_{j=0}^{L-1} c^*(j) \sum_{i=0}^{L-1} c\ (i)\ r_s(k, i-j)] \right\} \qquad (1)$$

where * represents complex conjugate, and $\arg \max_k f(k)$ means the value of k which maximises any function $f(k)$. Note that for many known spreading codes (e.g. Gold and Walsh codes) the contents of the square bracket in (1) are real in any case, and thus the operation Re (i.e. taking the real part of the square bracket) does not change the result.

Note that we have derived the expression for $m(k)$ in (1) from the RAKE receiver structure. The signal received in one finger of the RAKE receiver after correlation may be expressed as $\sum_{i=0}^{L-1} c(i) r_s(k,i)$, and each finger's contribution to the RAKE receiver output may be represented by one of the $c^*(j)\sum_{i=0}^{L-1} c(i) r_s(k,i-j)$, so that m(k) represents the overall RAKE receiver output. Thus, if the RAKE receiver 11 is replaced by a receiver which is not a RAKE receiver, $m(k)$ in equation (1) is preferably be modified appropriately.

(4). Unit 15 instructs a code request generation unit 17 to send a signal identifying the spreading code k with best performance to a resource allocating centre. In the case of an embodiment which is a cellular wireless telephone system, this centre is preferably in the base station. So, if the method according to the invention is being carried out by a CDMA receiver which is a mobile phone, then a signal will have to be transmitted to the base station, whereas if the CDMA receiver which is performing the invention is the base station itself, no transmission is necessary. Alternatively, one resource allocating centre may be shared by many base stations.

The resource allocating centre determines whether the requested code is available. If the required code is available and any other conditions are satisfied (for example, the priority of the radio link is the highest), the requested code is used to spread the symbols of that link. Note that the spreading codes used both uplink and downlink are preferably different.

Actually, if frequency division duplex is used, the uplink and downlink channels are also different.

(5). If the required spreading code is not available, the resource allocating centre will send some information to the receiver which issued that request. The code-selection block 15, selects the next best spreading code, and instructs the unit 17 to transmit a signal identifying that code.

(6). Repeat steps (4) and (5) until a spreading code is finally determined.

Figure 2 includes a unit 13 which notifies the unit 11 of changes in the spreading code. There are various ways in which unit 11 may operate. If the resource allocating centre is present in the receiver (e.g. in a cellular communication system, if the receiver is a base station containing a resource allocating centre) an electric connection can be provided from the resource allocating centre to the unit 13. In cellular comunications systems, the spreading codes determined by a base station may be notified to the mobile phones by a common communication channel which is shared by all users within the cell. However, alternatively, the code information may be transmitted along the same communication channel to which it relates using the previous spreading code. In a further alternative, unit 13 may not receive a message that a new code has been assigned, but actually deduce it from the CDMA signal.

(7). The RAKE receiver 11 despreads the received signals using the channel estimation from the unit 9 and the spreading code notified by the unit 13.

The proposed method can be used at either or both ends of the radio links of a CDMA communication system. For example, in a cellular wireless communication system, the channel can be either of a downlink and a uplink channel. The spreading codes can be any kind which have non-uniform

sidelobes at their auto-correlation functions, for example the Gold codes or Walsh codes (Orthogonal Variable Spreading Factor (OVSP) codes).

References

The disclosure of the following documents is incorporated herein by reference.

[1]. K.S. Gilhousen et al. "System and Method for Generating Signal Waveforms in a CDMA Cellular Telephone System", U.S. Patent No. 5,103,459.

[2] J. G. Proakis, "Digital Communications", 3rd edition, McGraw-Hill, 1995, pp 797 – 806.

[3]. Jiunn-Tsair Chen, C.B. Papadias and G. J. Foschini "Dynamic Signature Assignment for Direct-Secquence CDMA Systems", IEEE Communication Letters, Vol. 4, No. 6, 2000.

[4]. A. Duel Hallen, et al "Long-Range Prediction of Fading Signals", IEEE Signal Processing Magazine, Vol. 17, No. 3, May 2000.

CLAIMS

1. A method for assigning a spreading code to a communication device which is part of CDMA communication system in which a plurality of communication devices receive and/or transmit signals encoded by respective spreading codes, the method comprising the steps of:

deriving parameters of a multipath signal propagation channel for the device;

computing for each of a set of possible spreading codes a respective performance value using said derived channel parameters and an auto-correlation function of the corresponding spreading code;

selecting one of the possible spreading codes based on the performance values; and

assigning said selected spreading code to said device.

2. A method according to claim 1 in which said performance value of the k-th code is a value m(k) given by $m(k) = \mathrm{Re}[\sum_{j=0}^{L-1} c^*(j) \sum_{i=0}^{L-1} c(i) r_s(k, i-j)]$, where i is an integer $i = 0, \ldots, L-1$, the L values $\{c(i)\}$ are said derived parameters, each corresponding to a respective delay of i chip periods, and $r_s(k,i)$ is the auto-correlation of the k-th code at a delay of i chip periods.

3. A method according to claim 1 or claim 2 in which said selection step includes:

(1) assessing which of the set of possible spreading codes has the highest performance value;

(2) determining whether that spreading code fulfils one or more acceptance criteria,

(3) if in step (2) it is determined that that code fulfils the or each acceptance criterion, assigning that code to the device, and otherwise excluding that code from the set of possible spreading codes and returning to step (1).

4. A method according to claim 3 in which one said acceptance criterion is that the code is not presently in use by another device.

5. A method according to any preceding claim in which said step of deriving parameters is performed by measurement of a CDMA signal received by the device.

6. A communication device for use in a CDMA communication system in which a plurality of communication devices receive and/or transmit signals encoded by respective spreading codes, the device comprising:

antenna means for receiving CDMA signals;

decoding means for decoding the CDMA signals using a spreading code associated with the device;

means for deriving parameters of a multipath signal propagation channel associated with the antenna;

means for computing for each of a set of possible spreading codes a respective performance value using said derived channel parameters and an auto-correlation function of the corresponding spreading code;

means for selecting one of the possible spreading codes based on the performance values.

7. A device according to claim 6 in which said performance value of the k-th code is a function m(k) given by $m(k) = \mathrm{Re}[\sum_{j=0}^{L-1} c^*(j) \sum_{i=0}^{L-1} c(i) r_s(k, i-j)]$, where *i*

is an integer $i = 0,\ldots,L-1$, the L values $\{c(i)\}$ are said derived parameters, each corresponding to a respective delay of i chip periods, and $r_s(k,i)$ is the auto-correlation of the k-th code at a delay of i chip periods.

8. A device according to claim 6 or claim 7 in which said device includes:

assessment means for assessing which of the set of possible spreading codes has the highest performance value;

means for transmitting to a resource allocating centre a proposal that the spreading code with the highest performance value is associated with the device, and determining whether that centre accepts the proposal;

control means arranged, upon determining that the centre accepts the proposal, to transmit the spreading code with the highest performance value to the decoding means, and, upon determining that the centre rejects the proposal, to trigger said assessment means to operate again excluding the spreading code with the highest performance value from the set of possible spreading codes.

9. A CDMA communication system comprising a plurality of communication devices which receive and/or transmit signals encoded by respective spreading codes, and a resource allocation centre,

each device being arranged to use channel parameters of a channel associated with that device, and a respective auto-correlation function for each of a plurality of spreading codes, to generate a proposal for a spreading code to be associated with that device, and submit the proposal to the resource allocation centre;

the resource allocation centre being arranged to receive the proposals, determine if they meet approval criteria, and accordingly transmit approvals or disapprovals to the devices.

ABSTRACT

Resource Allocation in CDMA wireless communication systems

A dynamic assignment of the spreading codes of a user in a CDMA system is based on multipath channel conditions of that user. The spreading codes are assigned such that multipath signal energies are coherently integrated at the antenna of the receiver to ensure that the multipath components are summed constructively and therefore that a signal gain is obtained. The method is applicable to any CDMA system which uses spreading codes over a multipath channel. A specific algorithm for selecting the codes based on channel parameters and auto-correlation functions of the spreading codes is proposed.

Fig. 2

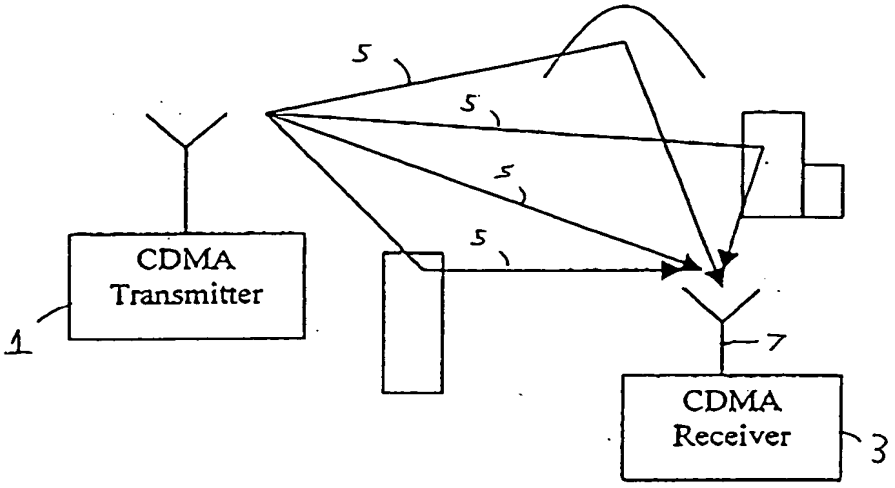

Figure 1

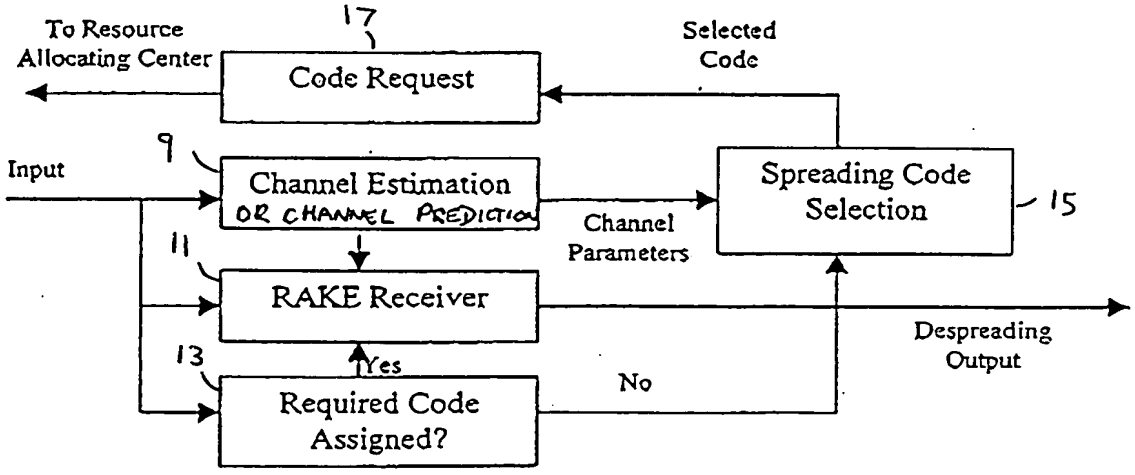

Figure 2